NEWS FROM AMRIS

Mapping Emotions Using 3 T MRI

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In recent years, functional magnetic resonance imaging (fMRI) has opened a new window onto the neural pathways underlying emotion and psychiatric disorders. This allows us to test our models of healthy and unhealthy brain function. Our lab recently applied this approach to obsessive-compulsive disorder (OCD). Our model supposes that OCD with obsessions about cleanliness and washing is not an anxiety disorder, but more accurately a disgust disorder. Our fMRI experiments suggest that the insula, a brain region implicated in disgust, is overactive in these patients.

Since functional imaging has only recently been used to study emotion, several useful but competing schemas exist for describing emotion. These models seem to mature in symbiosis with our understanding of their neural basis: they suggest new experiments and are in turn informed by the results. The biphasic theory of emotion is a simple but strong model that says emotional feelings and in particular the physical effects of emotion are produced by an approach system and an avoidance system. Thus our emotions can be described using two dimensions: valence (or pleasure), which means whether we feel nice or nasty, and arousal, which refers to the strength of our feelings.1 But while this model describes the reliable, physiological features of emotion well, it seems inadequate to describe the shifting panoply of emotional feelings. When asked to identify emotions in facial expressions, people can reliably identify six "basic" emotions regardless of culture: happiness, sadness, fear, anger, disgust and surprise.² While these labels are closer to social concepts than physiological states, there is evidence from lesion studies that disgust may be distinct from the other negative emotions. Patients with Huntingdon's disease and certain, specific strokes have been shown to be impaired both at identifying expressions of disgust and even at experiencing the feeling of disgust.³ It has been suggested that the somatosensory cortex allow conscious identification of emotions, and that since the insular cortex, which receives somatosensory input from the viscera, is specialized in recognizing disgust.

The first fMRI experiments to show distinct responses to disgust used pictures of facial expressions.⁴ Expressions of disgust evoked greater brain activation at the insula than expressions of other emotions, such as fear. But subsequent experiments using pictures of disgusting scenes, such as rotten food, yielded conflicting results. The first study of patients with OCD found an increased response in the insula to disgusting scenes in patients with the washing variety of OCD, but this study used no other emotion as a control.⁵ Two subsequent studies found that pictures inducing disgust and fear both caused equal activation of the insula, contrary to claims that the insula is an emotional specialist.^{6,7} Our lab combined these approaches and found a greater insula response in OCD patients to disgust-inducing pictures but not for fear-inducing pictures.⁸

While puzzling over these conflicting results, we noticed that the previous study comparing fear and disgust included gory pictures (such as injuries and corpses) in its disgust-inducing pictures, whereas ours did not. We therefore designed a study to compare disgust evoked by pictures of contamination with disgust evoked by pictures of mutilation. The first set contained pictures such as an overflowing toilet, cockroaches exploring a pizza, and piles of garbage. In the second set were pictures of traffic accidents, murder victims, tumors, and birth defects. We also included a fearinducing set of pictures of attacking dogs, snakes, gunmen, etc. and a neutral set of landscapes and household objects. In order to understand our subjects' responses better, we asked them to rate the pictures after their scan according to the six basic emotions (happiness, sadness, fear anger, disgust, and surprise). The pictures in this and the previous study were taken from the International Affective Pictures System (IAPS) and were already rated for the emotional dimensions of pleasure, arousal, and dominance.9

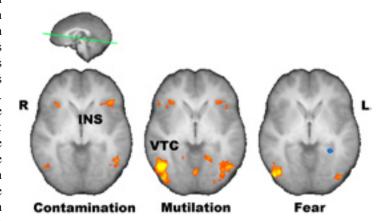


Figure 1. Statistical activation maps showing contrasts between each emotional condition and neutral. Contamination and mutilation caused activation of the anterior insula. The ventral visual cortex responded to all three emotional conditions, but only weakly to contamination. INS = insula, VTC = ventral temporal cortex. Green line in inset shows slice angle.

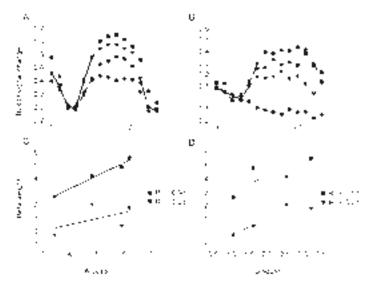


Figure 2. A & B: Averaged BOLD signal change (%) at the ventral visual area (A) and insula (B). Note the different relative responses between emotions at each region. ● = contamination, ■ = mutilation, ▼ = fear, ◆ = neutral. C & D: Emotion ratings plotted against modeled signal peak (Beta weight). Arousal predicted secondary visual activity (C), whereas disgust predicted activity in the anterior insula (D). ● = secondary visual cortex, ■ = anterior insula.

Surprisingly, we were able to recruit eight volunteers willing to endure these gruesome pictures. They were scanned using the 3 T Siemens Allegra scanner at the University of Florida's McKnight Brain Institute. We found again that the disgust picture sets evoked activity in the insula, but that fear pictures did not. We also saw increased activity in the secondary visual cortex for all emotion conditions. This has previously been noted as an effect of emotional arousal.10 When we took a closer look at the blood oxygen leveldependant (BOLD) responses in the insula and secondary visual cortex, we noticed that the response to the contamination pictures was greatest at the insula, but least at the secondary visual cortex (compared to the other emotional pictures). This suggested the two regions were processing different information. We confirmed this by correlating the peak activity at each region with our emotional ratings. Activity at the secondary visual cortex was predicted by pleasure and arousal ratings, whereas activity at the insula was predicted by the disgust rating. The reverse correlations were not significant.

Although these results strongly support the theory that the insula selectively processes disgust distinctly from emotional arousal, it is still not clear why some previous studies failed to find a specific insula response. The mutilation pictures induced comparable insula activity to the contamination pictures, and differed mostly in arousal of the secondary visual cortex. It is unlikely that they "diluted" the insula response to contamination pictures.

It is possible that the different findings were due to different scanner parameters. Perhaps the relatively small signal changes at the insula are only detectable at 3 T (the other studies used a 1.5 T scanner). But the most likely explanation comes, ironically, from

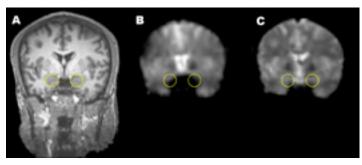


Figure 3. The effect of voxel size when imaging the amygdala. A: Structural image showing the left and right amygdala (circled) in the coronal plane. B: Identically positioned functional image from the disgust study showing susceptibility at the amygdala. Voxel resolution = $3.8 \times 3.8 \times 5$ mm. C: EPI image showing reduced susceptibility at the amygdala. Voxel resolution = $3.0 \times 3.0 \times 3.0$ mm.

a failed emotional experiment at our lab. The disgust study failed to show activity at the amygdala in response to emotional pictures because our scans failed to detect any signal in this region (this is due to the increased susceptibility artifact at 3 T). In order to study the amygdala, we reduced the voxel size in our functional scans from 3.8 mm in-plane resolution to 3.0 mm. This produced excellent images of the amygdala, but obliterated any contrast between the BOLD response to emotional and non-emotional conditions—even the reliable visual arousal effect. We confirmed this in a subsequent experiment comparing the response to fear-inducing pictures using both voxel-sizes: the larger 3.8 mm³ voxel scans were more sensitive to differences in the BOLD response to fear-inducing and neutral pictures. Both of the previous studies that found equal insula activity to fear and disgust used 3.0 mm voxels.

We plan to continue expanding our emotional studies, beginning with a series of validation studies to test the reliability of the BOLD response to emotion in various brain regions. The study presented here demonstrates the ability of high-field fMRI to detect subtle changes in brain activity between emotional conditions, and confirms that the insula is still a valid target for studies of disgust and OCD.

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